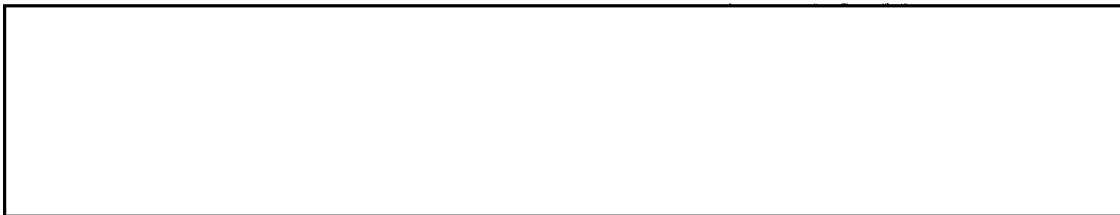


June 22, 1965

LINEAR PHASOLVER MEASURING ENGINE



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Measuring the measuring engine is a difficult proposition and linear measuring is tougher than rotary measuring because of scale factor variations.

So far, the test data seems to indicate that the Linear Phasolver electronics and patterns can measure to a fraction of 1/10 micron. [redacted] is trying to prove it by measuring gage block lengths. The variables they must contend with are:

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- a) Manual dexterity of the physical arrangement. The principal precaution is to not tilt the gage block and thus not measure a false length.
- b) Variations in null position of [redacted] microinch meter. Over short periods, this appears to be accurate to a few micro inches.
- c) Thermal variations in gage block lengths. They have obtained additional gage blocks to make a complete set for measuring 1/8 mm increments within the 1 mm pole pair length in addition to the five lengths of 23 mm, 30 mm, 60 mm, 125 mm, and 250 mm. Thus handling and thermal problems are decreased.
- d) Temperature and humidity effects on other components. Room temperature is continuously recorded and is within 1° F. Humidity is continuously recorded and is within about 3%.

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In a meeting at [redacted] on June 27, 1965, representatives of [redacted] reviewed the [redacted] Phasolver technique of measuring and inspected the linear phasolver feasibility model. The [redacted] representatives were: [redacted]

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He began the day highly skeptical of the practicability of the phasolver approach, particularly the electronics.

STAT [] was able to demonstrate better than 1/10 micron resolution and better than 1/2 micron peak to peak repeatability. By the end of the day, [] still had the following reservations:

- a) A laser interferometer by its geometry appeared to be easier to incorporate into a measuring machine than the phasolver.
- b) The phasolver cost of [] for a 2-axis system was high.
- c) In principle, a laser interferometer is much simpler and should be more accurate than the phasolver.
- d) The scale error in the present phasolver feasibility model would not meet his requirements.

STAT On the other hand [] and the others seemed to be convinced that:

- a) The linear phasolver did produce a unique, unambiguous measurement of position.
- b) There was no limitation on slewing rate from one measuring point to another.
- c) The velocity error was probably satisfactory for servo drive of a slaved platen to retain stereo registration while moving.
- d) Repeatability accuracy was 1/2 micron peak to peak or better.

STAT One additional point that came out of the meeting had to do with skew and tilt of the phasolver plates. Part of the [] test program calls for measurement of the sensitivity of phasolver accuracy to relative skew of the driver and coupler plates and variations of the gap between the plates, including tilt. [] indicated that the guiding ways and air bearings on his machine would hold skew to only a few seconds of arc and variations in the gap to 100 microinches ($2\frac{1}{2}$ microns), peak to peak. These variations are so small that measuring their effect on the phasolver is of second order of importance.

STAT [] has now turned their attention to scale factor. Scale factor error has two parts: a) error within a sine wave cycle pole pair (a pole pair is one millimeter long) and b) the incremental error from pole pair to pole pair

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over the 20 inch length. It should be noted that both these errors are systematic and can be corrected by computer computation.

Non-linear scale error within a pole pair can be corrected by balancing the amplitude and quadrature of the driver pattern exciting voltages. The uncorrected non-linear error was 60 microns p-p. By balancing, this has been brought down to about 1.8 micron p-p including repeatability error. (Note this is later data than the previously reported 0.8 micron p-p scale error.) Further reduction is probably possible.

The scale error over 250 mm is about 18 microns with about a 3 micron curvature (i.e. non linearity). In [] discussion with [] their consultant from UCLA, they decided that the resistance of the coupler pattern (which is about 2,000 ohms) was probably introducing a phase shift as it varied from near zero when measuring at one end to its maximum value when measuring at the other end. Tests this week and last tend to confirm that the coupler pattern resistance is causing the 3 micron non-linearity in the overall scale factor.

The cause of the linear error in the scale factor has not been determined. [] measurement of the patterns indicates the scale factor error should only be about 3 microns whereas the test data indicate it is about 18 microns. Thermal expansion or contraction of the glass bar on which the coupler pattern is placed may be a factor. If the temperature of the glass bar at the time of making the pattern at [] and measuring the pattern at [] is different by about 6.7°C from the temperature of the glass bar during the present test program, a scale factor error of the right magnitude could occur. Temperature difference is, however, probably only one contributor.

The [] accounting procedure has adjusted their man hour rates upward for the year due to increased overhead. This adjustment makes the contract over expended and they have officially stopped work. There is no estimate as to when they might resume work, if at all.

The next phase of the phasolver program should, it seems to me, be a check of the effect of temperature and humidity and probably should be run under the direction of [] to permit their thorough evaluation of the device. With [] concurrence I discussed the possibility of running such a test in the [] clean room with []

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General Manager of [REDACTED]

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[REDACTED] Both were in favor of such a test and will discuss it with John on his next trip.

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Unfortunately, the [REDACTED] clean room is not too well adapted to such a test. The rooms are not separately controlled. The present instrumentation will only produce 45% \pm relative humidity. It would probably be more suitable, but more expensive, to run the test in a commercial environmental chamber. [REDACTED] is planning to investigate the possibility of running a simultaneous test of a laser interferometer measuring device. He has nothing immediately at hand for such a test.

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